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(71) Applicant: EAGLE-TEK [US/US]; 7820 Sequoia Lane, Parkland, FL 33067 (US).

(72) Inventors: SCHULDT, David, A.; 7820 Sequoia Lane, Parkland, FL 33067 (US). SCHULDT, Craig, A.; 1636 Lee Drive, Mountain View, CA 94040 (US). NEMETH, Thomas, J.; 536 N.W. 44th Terrace #201, Deerfield Beach, FL 33433 (US).

(74) Agent: HAMRICK, Claude, A., S.; Bronson Bronson & McKinnon, Suite 600, Ten Almaden Boulevard, San Jose, CA 95113 (US).

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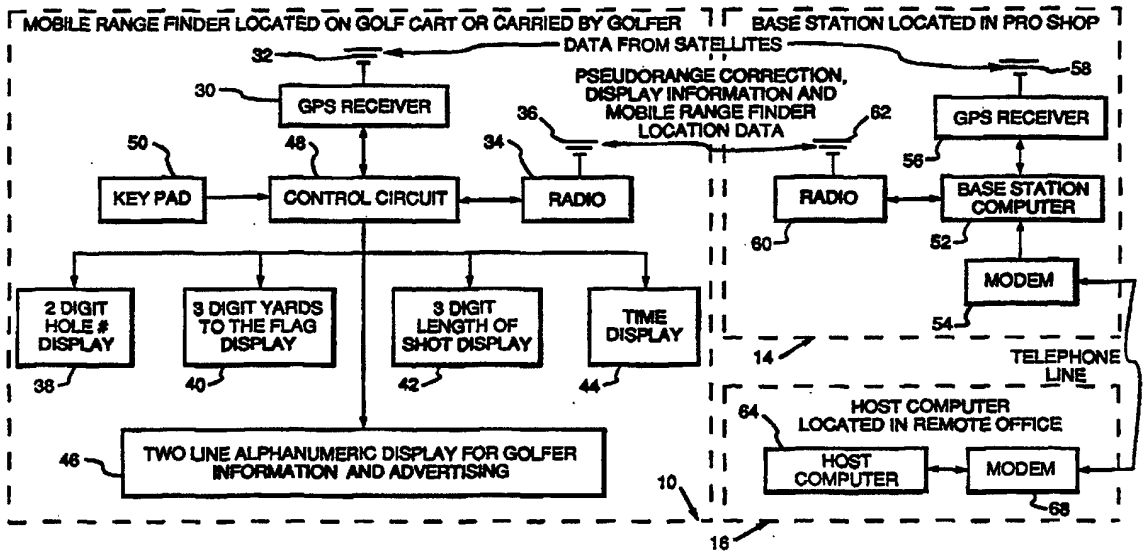

(57) Abstract

A method and apparatus for determining location and indicating selected distances between points on a golf course including a base station (14) having a GPS receiver (56), computer (52), and a radio frequency transmitter or transceiver (60), and a plurality of mobile range finder units (10) each having a GPS receiver (30), a radio frequency transmitter or transceiver (34), annunciators (38, 40, 42, 44), and a key pad (50). The base station (14) uses the GPS satellite information to continuously determine injected positional and system error and to transmit offset signals to the mobile units. The mobile units use the transmitted offset signals and independently received GPS location information to calculate actual position and altitude of the mobile unit and use positional information to calculate actual distance to and between selected points on the golf course.

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Specification

METHOD AND APPARATUS FOR DETERMINING LOCATION AND INDICATING SELECTED DISTANCES BETWEEN POINTS ON A GOLF COURSE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to position and distance determining apparatus and methods, and more particularly to a system and method for accurately determining the position of a golfer on a golf course and for calculating the distance from the golfer to various selected points on the course. The system also provides other information and provides for electronic golf course play management.

Description of the Prior Art

Numerous attempts have heretofore been made to improve management and profitability of golf course businesses by providing various means for assisting the players in determining various distances on the course so as to accelerate play of the game, and by providing means for tracking the position of golfers on the course for allowing the course executive to monitor the speed of play. Whereas fairway distances have classically been determined by referring to marked fairway or pathway points, more recent attempts at providing distance indication have included the use of various optical sighting devices, electromagnetic position detection systems and electronic ranging systems. For example, one such system described in US Patent No 4,703,444 utilizes three fixed transmitters located on the golf course to provide Rf ranging signals to portable interrogation units and a portable surveying unit to locate fixed features such as holes and hazards.

Another approach is disclosed in US Patent No 3,868,692 which describes a system utilizing RF transmitters located on each of the eighteen greens and an eighteen channel receiver that is carried by the golfer. The receiver measures the relative field strength of the Rf field generated by the transmitter on the green of interest to determine the range to the green.

In US Patent No 4,136,394 a system is described that utilizes a transducer located on each green which responds to a radio pulse generated by a remote unit carried by the golfer and generates a sonic or ultrasonic pulse that is received by the remote unit. The time required for the sound to travel from the green to the golfer is measured by the unit and the distance to the hole is calculated based upon the speed of sound and the elapsed time.

A radio transmission system using radio wave triangulation is disclosed in US Patent No 4,926,161 and a buried conductor electromagnetic detector system for determining distance to green information is disclosed in US Patent No 5,044,634.

Although not related to golf course applications, a somewhat relevant electronic vehicle locating system is disclosed in US Patent No 5,119,102. The system uses radio signals generated by the NAVSTAR Global Positioning System (GPS) satellites and vehicle carried receiving units capable of determining their position using information received from the satellites.

The NAVSTAR Global Positioning System is described in detail in numerous publications including "GPS NAVSTAR Users Overview" prepared and published by ARINC RESEARCH for the Program Director, NAVSTAR Global Positioning System Joint Project Office. Basically, the Global Positioning System includes a multitude of satellites in orbit around the earth at an altitude of approximately 10,500 miles. These satellites, which are commonly called NAVigation Systems using Timing And Ranging (NAVSTAR) satellites, are actively time synchronized by atomic

clocks and send information to earth via radio signals, such information including the location of the satellite, time information and range codes. The United States Department of Defense (DOD) monitors and maintains these satellites and provides access thereto free of charge to all users. The commercially usable signals received from the satellites are known as C/A code (course/acquisition) signals. The DOD causes pseudo-random noise to be injected into the C/A code to limit the accuracy of the C/A code signals. The intentionally injected noise signals, when combined with additional system errors such as satellite clock bias, atmospheric distortion and gravitational effects, limit the position determining accuracy of a ground based GPS receiver to approximately 100 yards of actual position. The use of a simple GPS receiver is thus not suited to use by a golfer to determine his position on a golf course fairway.

Furthermore, in addition to the problem of dealing with the injected noise signal and additional system errors, the simple use by a golfer of a GPS receiver to determine his position is not practical because such receiver provides position information in terms of longitudinal and latitudinal coordinates which must be interpreted in relation to a map of the region of interest, and such use would materially detract from play of the game.

SUMMARY OF THE PRESENT INVENTION

It is therefore a principal objective of the present invention to provide a system which makes transparent use of GPS technology and modern computer technology to provide accurate positional and distance information to golfers.

Another objective of the present invention is to provide a system of the type described which allows a golfer to determine the distance from his present position to a hole, hazard or other point on a golf course.

Still another objective of the present invention is to provide a system of the type described which allows a system operator and/or golf course manager to communicate information to a golfer on a real time basis.

A further objective of the present invention is to provide a system of the type described which can be used to substantially improve the management of a golf course by providing important information to a course operator or system manager.

Briefly, a preferred embodiment to the present includes a fixed base station having a GPS receiver, a base station computer and a radio frequency transmitter or transceiver, and a plurality of mobile range finder units each of which include a GPS receiver, a radio frequency receiver or transceiver, computational electronics annunciators and a key pad for user entry of information and/or selection of function. The function of the base station is to use GPS satellite information to continuously determine injected positional and system error and to transmit offset signals and other information to the mobile units. The mobile units in turn use the transmitted offset signals and independently received GPS location information to calculate actual position and altitude of the mobile unit and use such positional information as a means to compute actual distance to and between selected points on the golf course. The system may also include the capability of transmission from mobile unit to base station, and the base station may be coupled to a remotely located host computer which controls and/or monitors its operation.

An important advantage of the present invention is that it provides an easy to use electronic aide to golfers which enhances their play by providing them with accurate position and distance information.

Another advantage to the present invention is that it requires no additional use of optical or mechanical apparatus.

Another advantage to the present invention is that it serves to accelerate the speed of play of the game thereby enhancing the profitability of the golf course.

Still another advantage of the present invention is that it allows at least one-way communication between the club house and the players.

Yet another important advantage of the present invention is that it provides information which can be used to improve golf course management and facilities usage.

These and other advantages of the present invention will no doubt become apparent to those skilled in the art after having read the following detailed description of a preferred embodiment depicted in the several figures of the drawings.

DETAILED DESCRIPTION OF THE DRAWING

Fig. 1 is a pictorial view generally illustrating the environment and operational interrelationship of system components in accordance with the present invention.

Fig. 2 is a block diagram illustrating the principal operative components of a system in accordance with the present invention.

Fig. 3 is a pictorial view illustrating one possible design of a mobile range finder and annunciator unit in accordance with the present invention.

Fig. 4 is a block diagram generally illustrating the principal functional components of the control circuit of **Fig. 2**.

Fig. 5 is a flow chart illustrating operation of a GPS receiver.

Fig. 6 is a flow chart illustrating calculation and use of differential correction signals in accordance with the present invention.

Figs. 7a and 7b are flow charts illustrating overall operation of the system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to **Fig. 1** of the drawing, a pictorial view is presented showing a plurality of GPS satellites within view of a golf course having an installed golfer location and distance measuring system in accordance with the present invention. As depicted, the preferred embodiment is comprised of two main subsystems including a mobile range finder (MRF) unit 10 which is carried by a golfer, or mounted on a golf cart 12, and a base station 14 which is typically located in the pro shop. The system may also include a host computer system 16 housed in a location remote from the golf course. GPS receivers for receiving data broadcast from the NAVSTAR satellites a-e are disposed in each mobile unit 12 and the base station 14. In its simplest form the system requires only one centrally located general purpose communications transmitter, as evidenced by the antenna 18, to periodically broadcast differential correction signals and other information to a radio receiver in each mobile unit 10.

Whereas prior range measurement systems for golf courses have required the placement of numerous fixed sensors transmitters, transponders or markers on the golf course the present system requires no fixed facility other than the base station. The basic range measurement technique employed in the present invention is based upon a receiver only design for the mobile units. However, an alternative embodiment may also include a transmitter for communicating information back to the base station. As will be explained below, the system allows one or more golfers to obtain measurements of their range to the flag 20, to a sand trap 22, to a hazard 24, or the distance of a completed shot. Each mobile unit has the capability of quickly determining and displaying or audibly communicating correct range/distance information without interference from other mobile units on the course.

In an alternative embodiment the system also includes a transmitter in each mobile unit 10 to repetitively transmit information relating to its location back to the base station. Software allows the course operator to utilize such data to manage the golf course with improved efficiency and less cost than is now experienced. For instance if desired by the operator, the system will automatically track the speed of play of the group associated with each mobile unit on the course, and if any foursome should fall too far behind the group ahead of them, a message can be sent to the slow playing foursome to request that they speed up play. Alternatively, a course ranger could be notified of the delay on a specially addressed mobile unit. The mobile transmitters and receivers, and the base station transmitter and receiver can also be used as a means of providing intercommunication between players and clubhouse.

As indicated above, the use of a GPS receiver to determine position is well known. However, the difficulty of use and the inherent inaccuracies associated with use of such a receiver alone make it impractical for golf applications. The DOD injected noise signals combined with additional system errors such as satellite clock bias, atmospheric distortion and gravitational effects limit the position determining accuracy of a ground based GPS receiver to a distance clearly outside the range of usefulness to a golfer. Thus, in addition to the GPS receiver, the present invention includes means to determine such errors and then, through additional signal processing, eliminate the error and determine the "true" position of the mobile unit.

The system utilizes a technique called "real time differential positioning" to continuously and accurately determine the actual location of each mobile receiver and thus, the position of the corresponding golfer on the course. In accordance with the present invention the coded satellite range signals transmitted by each orbiting

satellite are simultaneously received by the GPS engines in both the base station 14 and each mobile unit 10, and are processed by microprocessors which compute location and distance (and altitude) solutions. However, the computations made at the base station differ from the ultimate computations made in the mobile units.

To remove the pseudo random errors injected by the DOD as well as additional system error, such as satellite clock bias, atmospheric distortion and gravitational effect and thus achieve the required accuracy of less than three yards, the GPS base station receiver installed at a known permanent golf course location, such as the pro shop, determines its apparent position and computes an offset to its actual position.

More specifically, upon installation, the precise location (latitude, longitude and altitude) of the base station is determined via GPS survey techniques and is recorded into the computer's system memory. The base station receiver thus continuously determines its apparent location in the same manner as does each mobile unit. However, because the base station receiver was programmed during its installation to know precisely where it is actually located and since it does not move, it can use its known location and the calculated "apparent location" to continuously determine the amount of error or "offset". The offset information can then be periodically sent via radio transmission to each mobile unit operating on the course, and each mobile unit can in turn apply such information as a correction factor to its own calculated location. The result of this calculated solution provides an accurate indication of the location of each mobile unit at any point that such information is desired.

To then determine the distance from the mobile unit to a hole (or hazard) requires that the mobile unit also know where the hole (or hazard) is located. Since the hole location is normally moved on the green daily, the course operator must establish a fixed number of locations

or sectors (generally 3-7 per green) where the hole will be placed, and develop a schedule for the preassigned hole placement. A hole location schedule is then loaded into the base station computer and, as each mobile unit is turned on, the base station computer transmits a message to the unit telling it the location of each hole on each green for that particular day, and the locations of particular points on the hazards, e.g. a near side point and a far side point. This location information is then stored in the mobile unit's memory and is subsequently used to calculate the precise distance from the cart to the hole or hazard. However, the software in the base station computer allows the golf course operator to override the pre-programmed daily pin placement and hazard location schedule for any or all fairways if so desired.

The calculation of distance using GPS receivers is incorporated in many types of navigation equipment which in most cases require that the manufacturer or the operator of the equipment enter the coordinates of a fixed point of interest. However, unlike such prior art systems, the present invention automatically transmits the location and altitude of the fixed points, holes and hazards, etc. to the mobile unit, thus eliminating the need for operator input. This information is transmitted on the same radio channel that is used for the differential correction signal.

Since the mobile unit is located on a golf cart, or is carried by a golfer, it can, by comparing its calculated and corrected position coordinates to the internally stored coordinates of a pin or hazard, provide a direct distance and altitude measurement to a particular hole or hazard without the need for the additional substraction of any estimated offset distances from markers such as water sprinkler heads or other permanently imbedded markers in the fairway.

The mobile range finder unit also includes the capability of measuring and displaying the distance the

ball has traveled for any golf shot made by the golfers using the system. This feature can be activated for any or all shots as desired by the individual player.

In that the system also incorporates a means of counting the number of rounds of play for which each mobile unit is actually used, this feature gives the system owner the ability to charge the golf course operator a fee based upon the usage of the units. In a typical case, the golf course operator will regularly pre-purchase the right to use the mobile units for a specific number of rounds of golf depending upon their expected usage. These pre-purchased rounds will then be programmed into the memory of the golf course base station computer by means of an electronic download via a telephone modem hookup arrangement from an automatic, host computer system at some remote location. The host computer will simultaneously transfer the credits for the purchased number of rounds to the particular base station and automatically generate the appropriate invoice and other accounting information on the base station printer at the golf course. Purchased rounds will first be stored in the base station computer of the golf course and then be individually transferred to the respective mobile units as required via a signal over the base station radio transmitter. One credit will be extended each time a mobile unit is turned on from the base station. Once turned on, the mobile unit will work for only the time period normally required to complete a round of golf, with enough spare time allowed to insure that every round can actually be completed.

Referring now to **Fig. 2** of the drawings, the principal functional components of the mobile range finder and annunciator unit 10, the base station 14, and the remote office 16 are depicted in a block diagram. A subsystem in the mobile unit 10 includes an electronic module that consists of a global positioning receiver 30, a GPS antenna 32, a radio modem 34 having a radio antenna

36, numeric displays 38, 40, 42 and 44, and an alpha numeric display 46, control circuitry 48, and front panel keypad switches 50 all housed in a weather proof enclosure which may resemble that illustrated in **Fig. 3** of the drawing. The unit is preferable securely mounted to the dashboard of a golf cart and is wired to obtain its power from the cart batteries. Alternatively, the unit may include batteries and be carried by a golfer. Furthermore, in addition to the visual information displays 38-44 the unit 10 may include a speaker and perhaps a microphone (not shown) to permit audible communication as well.

The base station 14 is generally located in the clubhouse or pro shop of the golf course and includes a general purpose computer 52 with custom software, a modem 54, a GPS receiver 56, a GPS antenna 58, a radio modem 60 and a radio antenna 62. The base station computer 52 is used to generate display messages to each of the mobile units, to order additional rounds of play from the system owner, store credits or prepurchased golf rounds, configure the mobile units for the daily pin locations, store the course configuration information, and provide system accounting information. The base station GPS receiver 56 receives satellite data, calculates the differential correction (offset) data, and with the aid of computer 52 sends it to the mobile range finder units via the base station radio 60. Such computation could also be done by the base station computer 52 if the GPS receiver does not have the capability. Data received from the host computer 64 at the remote office 16 via the hookup of modems 68 and 54 is used for accounting information or is sent via the radio modems 60 and 34 to the mobile range finders.

The remote office 16 includes a general purpose computer 64 with custom software and a modem 68. The host computer 64 is used by the system executive or owner to allow a base station operator to automatically purchase

and download additional usages of the mobile range finder units. It also provides a means for the system owner to communicate with the base station computer and therefore each mobile range finder unit. This communications network can also be used to provide display information to the mobile range finder units as well as giving the system owner the ability to perform remote diagnostics and provide program updates to both the base station, or stations, and the mobile range finder units.

In **Fig. 3** of the drawing, the simplicity of use of the present invention is suggested by the depiction of a mobile unit 10 of the type that might be mounted on a golf cart. As previously mentioned, upon start of a round the elapsed time clock 44 will commence keeping time. The hole number being played will be selected using buttons 37 and 39 and indicated at 38. In case holes are played out of order, one can change the hole number by pressing one of the UP or DOWN buttons 37 or 39. Following commencement of play the initial yardage to the hole or flag will be indicated on indicator 40.

If the player wishes to determine the distance to the front edge of a hazard, the pressing of button 41 will cause the yardage indicated in the display 40 to change to indicate such distance. Similarly, if the button 43 is depressed, the distance required to clear the hazard will be indicated. Furthermore, if there is a significant difference between the course altitude and the altitude of the green or hazard, the altitude difference may be displayed in the window 46.

If after having hit a particular shot, the golfer pushes his START button 45, and then after having arrived at the position of his ball, pushes the END button 47, the length of his shot will be displayed at 42. Note that the distance of each players' shot can be alternatively indicated by pressing buttons 45/47. Although a particular combination of buttons and displays is illustrated, any similar configuration can be used.

During play the subsystem can automatically generate appropriate messages for display on the two lines 46, or alternatively, messages transmitted from the base station or remote office can be displayed. Note also that if the unit includes transmission capability it may also have a microphone and speaker, and perhaps an expanded keyboard to permit data entry.

Turning now to **Fig. 4**, the principal functional components of the control circuit 48 of the mobile unit 10 are depicted in block diagram form. The circuit is a custom designed assembly including Universal Asynchronous Receivable Transmitters (UART's) 70 and 72, a microprocessor 74, random access memory 76, program storage memory 78, and read only memory or flash programmable memory, display drivers 80 and a power supply 82.

The microprocessor 74 receives position data via the UART 70 from the mobile unit's GPS receiver 30, receives display information, configuration data, program updates and differential correction data via UART 72 which communicates via modems 34 and 60 (**Fig. 2**) with the base station computer 52. The microprocessor also receives user control inputs via input line 49 from the key pad 50 (**Figs. 2 and 3**).

Each mobile unit's GPS receiver and the base station's GPS receiver are capable of tracking, receiving data from multiple satellites and normally selects a set of the four satellites with best geometry to utilize in making its calculation. **Fig. 5** is a flow chart providing a basic indication of how a GPS receiver calculates the location of the receiver and **Fig. 6** is a flow chart illustrating how the differential correction data is generated and applied.

More specifically, ranging signals are provided by the NAVSTAR satellites and are received by the GPS receivers as indicated in **Fig. 5**. Upon receiving the satellite data, each receiver calculates the distance

(pseudorange) from each selected satellite to the receiver. Each distance is given by the formula

$$PR_i = \Delta T_i \times c$$

where PR_i is the pseudorange from satellite i, T_i is the time it takes the range signal to travel from satellite i to the GPS receiver, and c is the speed of light.

In addition to range signals, the satellites transmit satellite ephemeris data to the receiver, i.e., a list of accurate locations of the satellites as a function of time. This gives the receiver the location of each satellite expressed as X_i, Y_i and Z_i. The variable i is used to designate the satellite. With the data from the four best satellites (b, c, d and e in **Fig. 1**) that are in view of the GPS antenna, the receiver's data processor solves a matrix of four equations for four variables:

$$(X_1 - UX)^2 + (Y_1 - UY)^2 + (Z_1 - UZ)^2 = (PR_1 - (CB \times c))^2$$
$$(X_2 - UX)^2 + (Y_2 - UY)^2 + (Z_2 - UZ)^2 = (PR_2 - (CB \times c))^2$$
$$(X_3 - UX)^2 + (Y_3 - UY)^2 + (Z_3 - UZ)^2 = (PR_3 - (CB \times c))^2$$
$$(X_4 - UX)^2 + (Y_4 - UY)^2 + (Z_4 - UZ)^2 = (PR_4 - (CB \times c))^2$$

The variables UX, UY and UZ are respectfully the latitude, longitude and altitude of the receiver, and CB is the receiver clock bias. The receiver clock bias is the difference between the satellite time and the receiver time. This data incorporates errors which include pseudorandom errors injected by the DOD and additional system errors such as satellite clock bias, atmospheric distortion and gravitational effects. These errors limit the accuracy of the basic GPS to approximately 100 meters.

Fig. 6 depicts the calculation and application of the differential correction data which is required to improve the system accuracy to within approximately two yards as required in the sport of golf. The base station GPS receiver is fixed in location and the exact actual location of the receiver given by the coordinates AX, AY

and AZ is determined at the time of installation utilizing GPS survey techniques. The base station GPS receiver is given this location by the base station computer and uses such information along with the basic GPS location calculations of UX, UY and UZ to determine the error associated with the pseudorange data (PRC_i) from each satellite that is being tracked by the base station GPS receiver. This pseudorange correction data is sent from the base station GPS receiver to the base station computer which, in turn, sends the data to the mobile units via the radio modems. The receiver in each mobile unit solves the basic set of equations as set forth above with the added pseudorange correction factor PRC_i as follows:

$$(X_1 - UX)^2 + (Y_1 - UY)^2 + (Z_1 - UZ)^2 = ((PR_1 + PRC_1) - (CB \times c))^2$$
$$(X_2 - UX)^2 + (Y_2 - UY)^2 + (Z_2 - UZ)^2 = ((PR_2 + PRC_2) - (CB \times c))^2$$
$$(X_3 - UX)^2 + (Y_3 - UY)^2 + (Z_3 - UZ)^2 = ((PR_3 + PRC_3) - (CB \times c))^2$$
$$(X_4 - UX)^2 + (Y_4 - UY)^2 + (Z_4 - UZ)^2 = ((PR_4 + PRC_4) - (CB \times c))^2$$

Generally stated, the method of the present invention is depicted in **Figs. 7a** and **7b** and includes the following steps:

(a) Using a mobile first GPS receiver to obtain signals transmitted from at least three (and preferably four) NAVSTAR satellites and to calculate first pseudorange data based on the time at which each transmitted signal is received by the mobile receiver;

(b) Using a second GPS receiver disposed at a fixed, known position to obtain signals transmitted from at least three (and preferably four) NAVSTAR satellites and to calculate second pseudorange data based on the time at which each transmitted signal is received by the second GPS receiver;

(c) Using the calculated second pseudorange data to determine the measured position of the base station;

(d) Using the known position and the measured position to develop a differential correction offset signal;

(e) Transmitting the differential correction offset signal to the remote mobile receivers;

(f) Receiving the transmitted differential correction offset signal at the remote mobile receiver and using it and the first pseudorange data to determine the actual position of the mobile unit; and

(g) Using the actual position information to determine and indicate the distance between the mobile unit and a known position on the golf course.

The following additional steps can also be implemented:

(h) Using the actual position information obtained at one location and the actual position information subsequently obtained at another location to calculate the distance between the two locations;

(i) Transmitting the actual position information back to the base station; and

(j) Receiving the transmitted actual position information at the base station and using same to monitor the travel of the mobile unit over the golf course.

Moreover, if signals from four satellites are processed the indication provided in step (g) can also include the difference in altitude between the mobile unit and the known position of the golf course.

As pointed out above, the method can also include transmission of information in both directions between the mobile unit and the base station, transmission of information in both directions between the remote office and the base station, and control of mobile unit and/or base station operation from the remote office, etc.

Whereas the best available prior art golf distance measurement systems use only three land based transmitters and do not provide for switching to an optimum set of transmitters to insure best accuracy, in accordance with the present invention, multiple satellite signals can be received and the best combination thereof automatically and dynamically selected to calculate the most accurate

position based upon relevant signal strengths and optimum satellite geometries. While only three satellites are required for a two dimensional solution, and only four are required for a three dimensional solution, there are currently twenty-four satellites available in the NAVSTAR system with up to eleven in view at any particular time to provide a system usage/capability significantly more independent of terrain or location than was previously available in the prior art.

The present invention provides a triangulation capability in a "vertical" orientation versus the "horizontal" orientation of the prior art, land-based systems. This makes it possible to provide the height difference between the golfer's location and the green, a measurement that was not possible with prior art devices. This vertical orientation allows wide spread use of the technology in the sport of golf, where the prior art was inaccurate, unreliable or even unusable in those golf course locations where terrain or buildings, such as houses or condominiums, masked or blocked the electronic line-of-site between the transmitter and the player or his cart. The satellite signals used in the present invention are available virtually anywhere on earth and do not require that triangulation transmitters be installed on the golf course.

Whereas prior art systems utilize ground based triangulation techniques which essentially solve three equations for the variables X location, Y location and time. The present invention incorporates a real time differential correction system to correct for intentionally injected noise, clock timing errors, atmospheric distortion and other variables. The use of differential correction allows for the resolution of an additional variable, system error, which greatly improves system accuracy.

Moreover, the present invention enables the development of an extensive data network that allows the

system operator and the system owner to send data to, and receive data from, each mobile range finder unit. The utilization of time multiplexing of radio modems allows the system to transmit golf course configuration data, display messages, diagnostic data, computer program updates and real time differential correction data. The use of flash memory for the mobile unit microprocessor program memory, in conjunction with the data network, allows for program updates and modifications that can be generated automatically. The present invention also includes the capability of automatically down loading usage credits for usage, and simultaneously generating invoices and accounting information.

Although the present invention has been described above with regard to a particular preferred embodiment of the present invention. It is contemplated that after having read such disclosure certain alterations and modifications thereof will become apparent to those skilled in the art. It is therefore intended that the following claims be interpreted as covering all such alterations and embodiments as fall within the true spirit and scope of the invention.

What is claimed is:

CLAIMS

1. A system for determining a golfer's position and distance between various points on a golf course, comprising:

a base station having a known position and including

a global positioning system (GPS) receiver for receiving and using signals transmitted by NAVSTAR to determine its apparent position,

computing means for determining a differential position offset equal to the difference between said known position and said apparent position, and

transmitter means for transmitting information proportional to said differential position offset; and

at least one mobile range finder unit including

a GPS receiver for receiving and using signals transmitted by said NAVSTAR satellites to develop an apparent mobile unit position signal,

radio receiver means for receiving said differential position offset information, and

computing means for using said apparent mobile unit position signal and said differential position offset information to determine the actual position of said mobile unit on said golf course and for determining and developing a distance signal proportional to the distance between said actual position and a selected predetermined position on said golf course, and

annunciator means responsive to said distance signal and operative to indicate said distance.

2. A system as recited in claim 1, wherein said transmitter means also has the capability of transmitting communicative information and, wherein, said receiver means receives said communicative information and in response thereto said annunciator means communicates such information to a golfer associated with said mobile unit.

3. A system as recited in claim 1 wherein said mobile unit computing means is capable of determining the distance between any two selected positions of said mobile unit, and said annunciator means is operative to indicate such distance to a golfer associated with said mobile unit.

4. A system as recited in claim 3 wherein said annunciator means includes a visual display means for indicating distances in yards.

5. A system as recited in claim 2 wherein said annunciator means includes a visual display means for displaying said communicative message.

6. A system as recited in claim 1, wherein said mobile unit further includes transmitter means for transmitting said actual position information and/or user input information, and wherein said base station further includes radio receiver means for receiving said transmitted actual position information and/or said user input information.

7. A method of determining and indicating the distance between two points on a golf course, comprising:

(a) using a mobile first GPS receiver to obtain signals transmitted from at least three NAVSTAR satellites and to calculate first pseudorange data based on the time at which each transmitted signal is received by the mobile receiver;

(b) using a second GPS receiver disposed at a fixed, known position to obtain signals transmitted from at least three NAVSTAR satellites and to calculate second pseudorange data based on the time at which each transmitted signal is received by the second GPS receiver;

(c) using the calculated second pseudorange data to determine the measured position of the base station;

(d) using the known position and the measured position to develop a differential correction offset signal;

(e) transmitting the differential correction offset signal to the remote mobile receivers;

(f) receiving the transmitted differential correction offset signal at the remote mobile receiver and using it and the first pseudorange data to determine the actual position of the mobile unit; and

(g) using the actual position information to determine and indicate the distance between the mobile unit and a known position on the golf course.

8. A method as recited in claim 7 and further comprising:

(h) Using the actual position information obtained at one location and the actual position information subsequently obtained at another location to calculate the distance between the two locations.

9. A method as recited in claim 8 and further comprising:

(i) Transmitting the actual position information back to the base station; and

(j) Receiving the transmitted actual position information at the base station and using same to monitor the travel of the mobile unit over the golf course.

10. A method as recited in claim 7 and further comprising:

(k) Using the actual position information obtained at the location of the mobile unit and actual position information regarding another location to calculate the difference in altitude between the two locations.

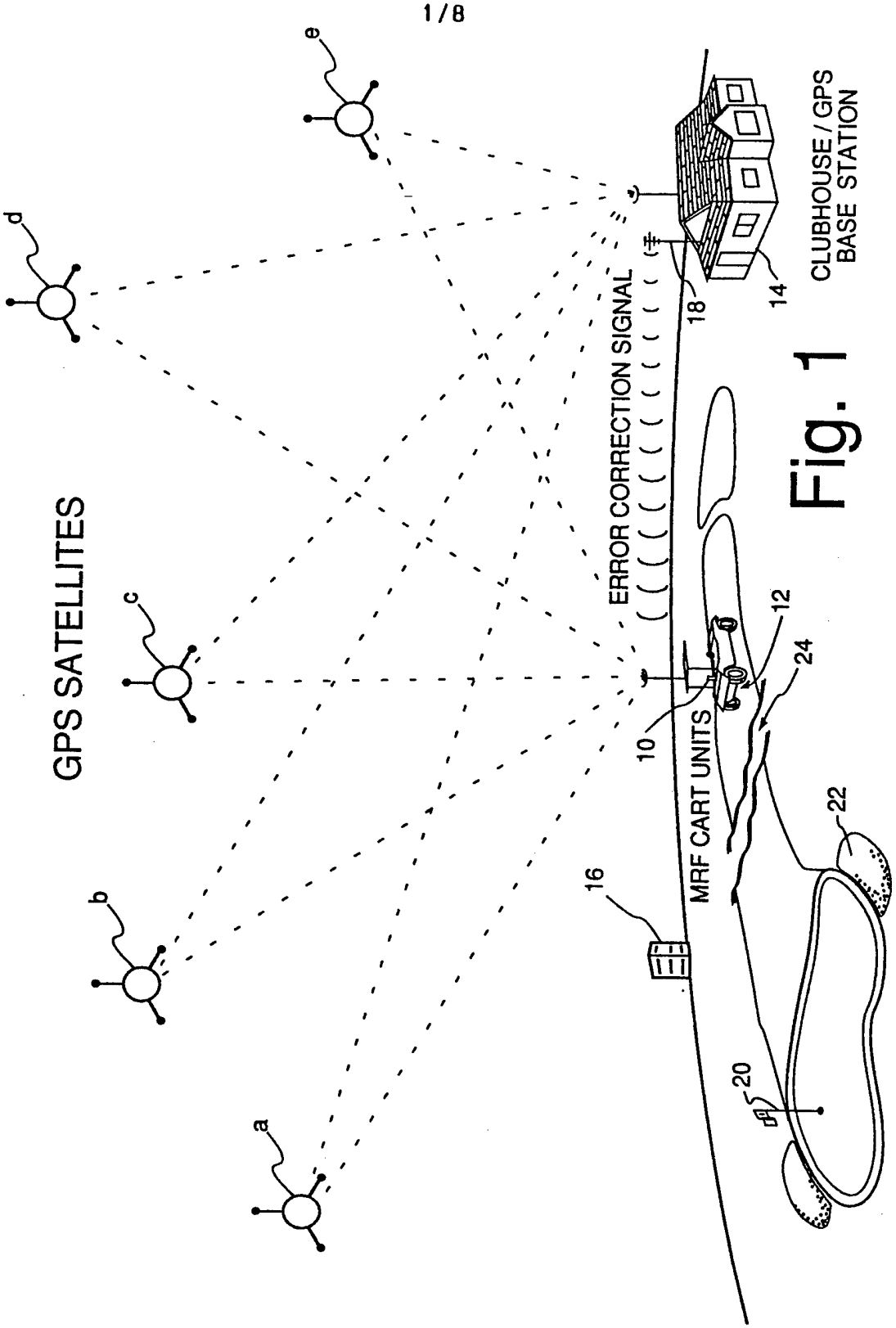
GPS SATELLITES
a
b
c
d
e
ERROR CORRECTION SIGNAL
CLUBHOUSE / GPS BASE STATION
MRF CART UNITS
10
12
14
16
18
20
22
24

Fig. 1

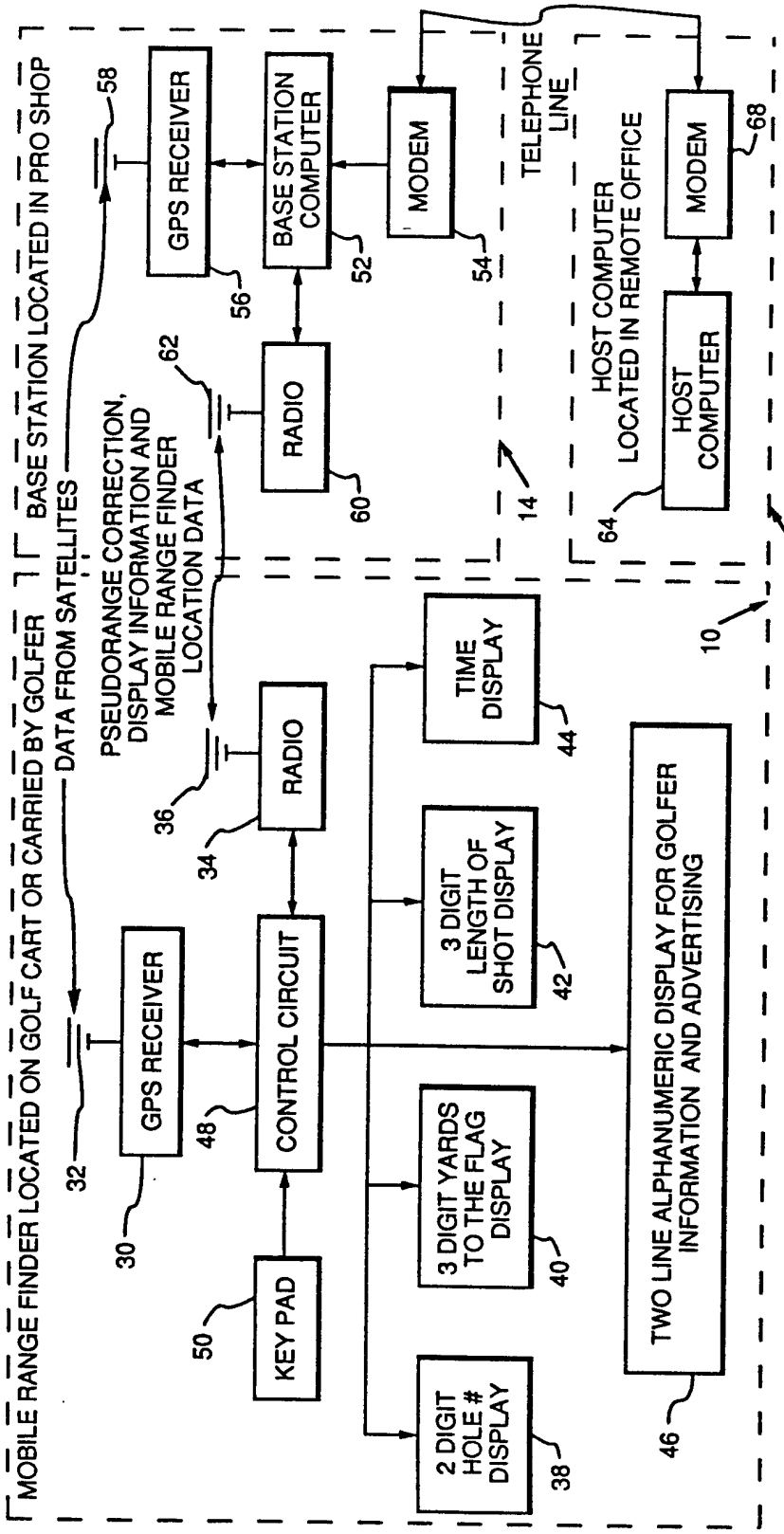
MOBILE RANGE FINDER LOCATED ON GOLF CART OR CARRIED BY GOLFER
BASE STATION LOCATED IN PRO SHOP
DATA FROM SATELLITES
PSEUDORANGE CORRECTION, DISPLAY INFORMATION AND MOBILE RANGE FINDER LOCATION DATA
TELEPHONE LINE
HOST COMPUTER LOCATED IN REMOTE OFFICE
GPS RECEIVER
BASE STATION COMPUTER
MODEM
MODEM
HOST COMPUTER
RADIO
RADIO
GPS RECEIVER
CONTROL CIRCUIT
KEY PAD
TIME DISPLAY
3 DIGIT LENGTH OF SHOT DISPLAY
3 DIGIT YARDS TO THE FLAG DISPLAY
2 DIGIT HOLE # DISPLAY
TWO LINE ALPHANUMERIC DISPLAY FOR GOLFER INFORMATION AND ADVERTISING
10
14
16
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
68

Fig. 2

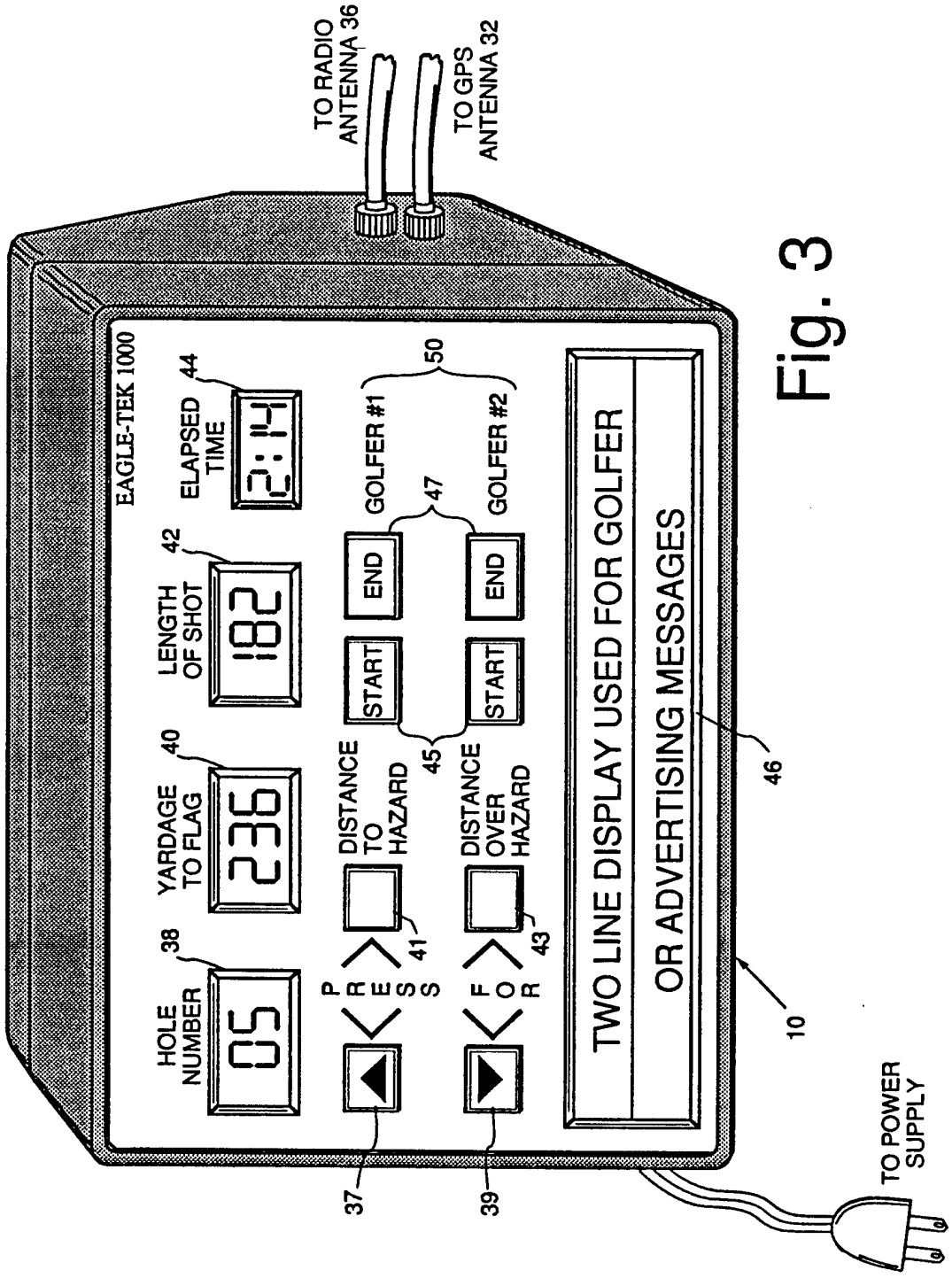
TO RADIO ANTENNA 36
TO GPS ANTENNA 32
EAGLE-TEK 1000
ELAPSED TIME
2:14
44
LENGTH OF SHOT
182
42
YARDAGE TO FLAG
236
40
HOLE NUMBER
05
38
DISTANCE TO HAZARD
DISTANCE OVER HAZARD
PRESS
FOR
41
43
START
END
START
END
45
47
GOLFER #1
GOLFER #2
50
TWO LINE DISPLAY USED FOR GOLFER
OR ADVERTISING MESSAGES
46
10
37
39
TO POWER SUPPLY

Fig. 3

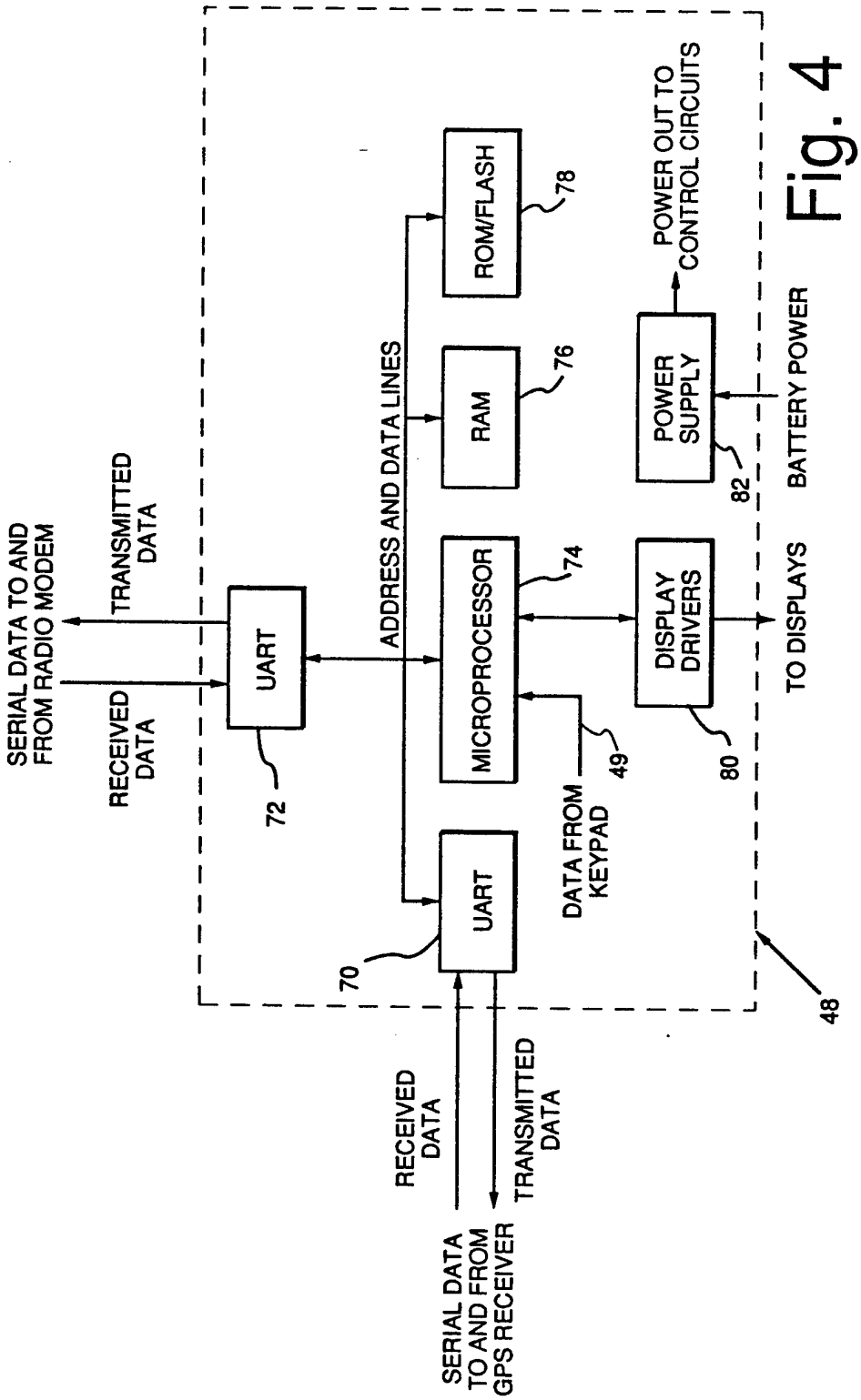
SERIAL DATA TO AND FROM RADIO MODEM
TRANSMITTED DATA
RECEIVED DATA
UART
72
ADDRESS AND DATA LINES
MICROPROCESSOR
74
DATA FROM KEYPAD
49
UART
70
RECEIVED DATA
TRANSMITTED DATA
SERIAL DATA TO AND FROM GPS RECEIVER
RAM
76
ROM/FLASH
78
DISPLAY DRIVERS
80
TO DISPLAYS
POWER SUPPLY
82
BATTERY POWER
POWER OUT TO CONTROL CIRCUITS
48

Fig. 4

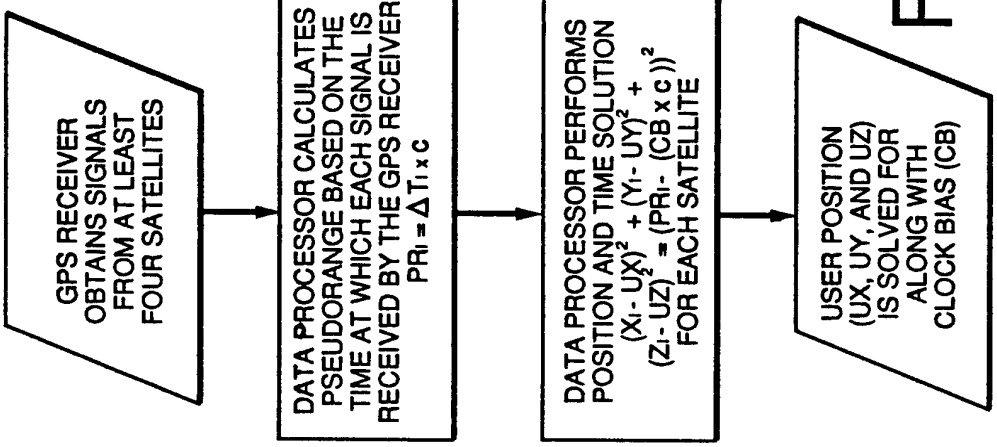
GPS RECEIVER OBTAINS SIGNALS FROM AT LEAST FOUR SATELLITES
DATA PROCESSOR CALCULATES PSEUDORANGE BASED ON THE TIME AT WHICH EACH SIGNAL IS RECEIVED BY THE GPS RECEIVER PRi = ΔTi x c
DATA PROCESSOR PERFORMS POSITION AND TIME SOLUTION (Xi - UX)² + (Yi - UY)² + (Zi - UZ)² = (PRi - (CB x c))² FOR EACH SATELLITE
USER POSITION (UX, UY, AND UZ) IS SOLVED FOR ALONG WITH CLOCK BIAS (CB)

Fig. 5

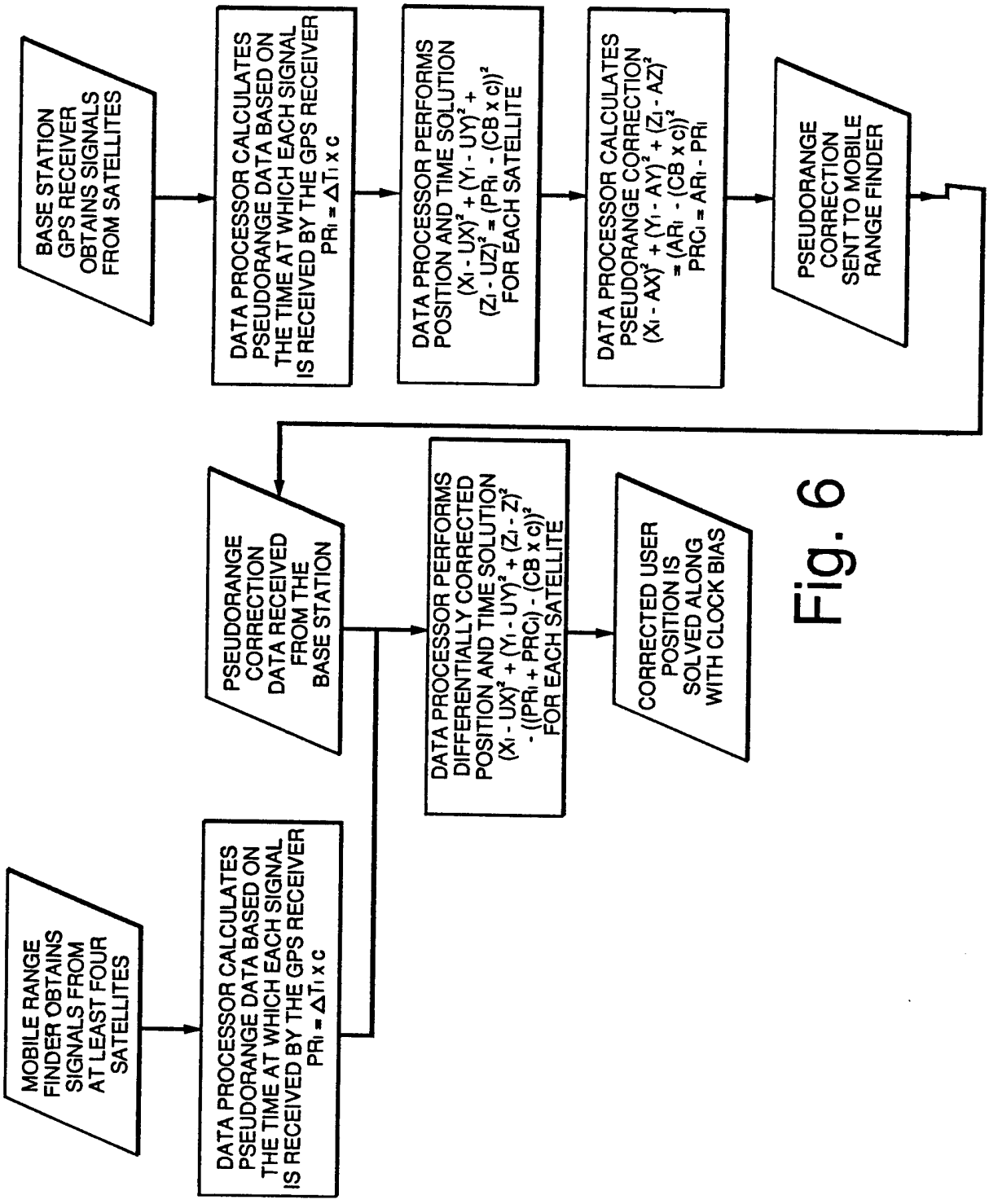
BASE STATION GPS RECEIVER OBTAINS SIGNALS FROM SATELLITES
DATA PROCESSOR CALCULATES PSEUDORANGE DATA BASED ON THE TIME AT WHICH EACH SIGNAL IS RECEIVED BY THE GPS RECEIVER PRi = ΔTi x c
DATA PROCESSOR PERFORMS POSITION AND TIME SOLUTION (Xi - UX)² + (Yi - UY)² + (Zi - UZ)² = (PRi - (CB x c))² FOR EACH SATELLITE
DATA PROCESSOR CALCULATES PSEUDORANGE CORRECTION (Xi - AX)² + (Yi - AY)² + (Zi - AZ)² = (ARi - (CB x c))² PRCi = ARi - PRi
PSEUDORANGE CORRECTION SENT TO MOBILE RANGE FINDER
PSEUDORANGE CORRECTION DATA RECEIVED FROM THE BASE STATION
MOBILE RANGE FINDER OBTAINS SIGNALS FROM AT LEAST FOUR SATELLITES
DATA PROCESSOR CALCULATES PSEUDORANGE DATA BASED ON THE TIME AT WHICH EACH SIGNAL IS RECEIVED BY THE GPS RECEIVER PRi = ΔTi x c
DATA PROCESSOR PERFORMS DIFFERENTIALLY CORRECTED POSITION AND TIME SOLUTION (Xi - UX)² + (Yi - UY)² + (Zi - Z)² - ((PRi + PRCi) - (CB x c))² FOR EACH SATELLITE
CORRECTED USER POSITION IS SOLVED ALONG WITH CLOCK BIAS

Fig. 6

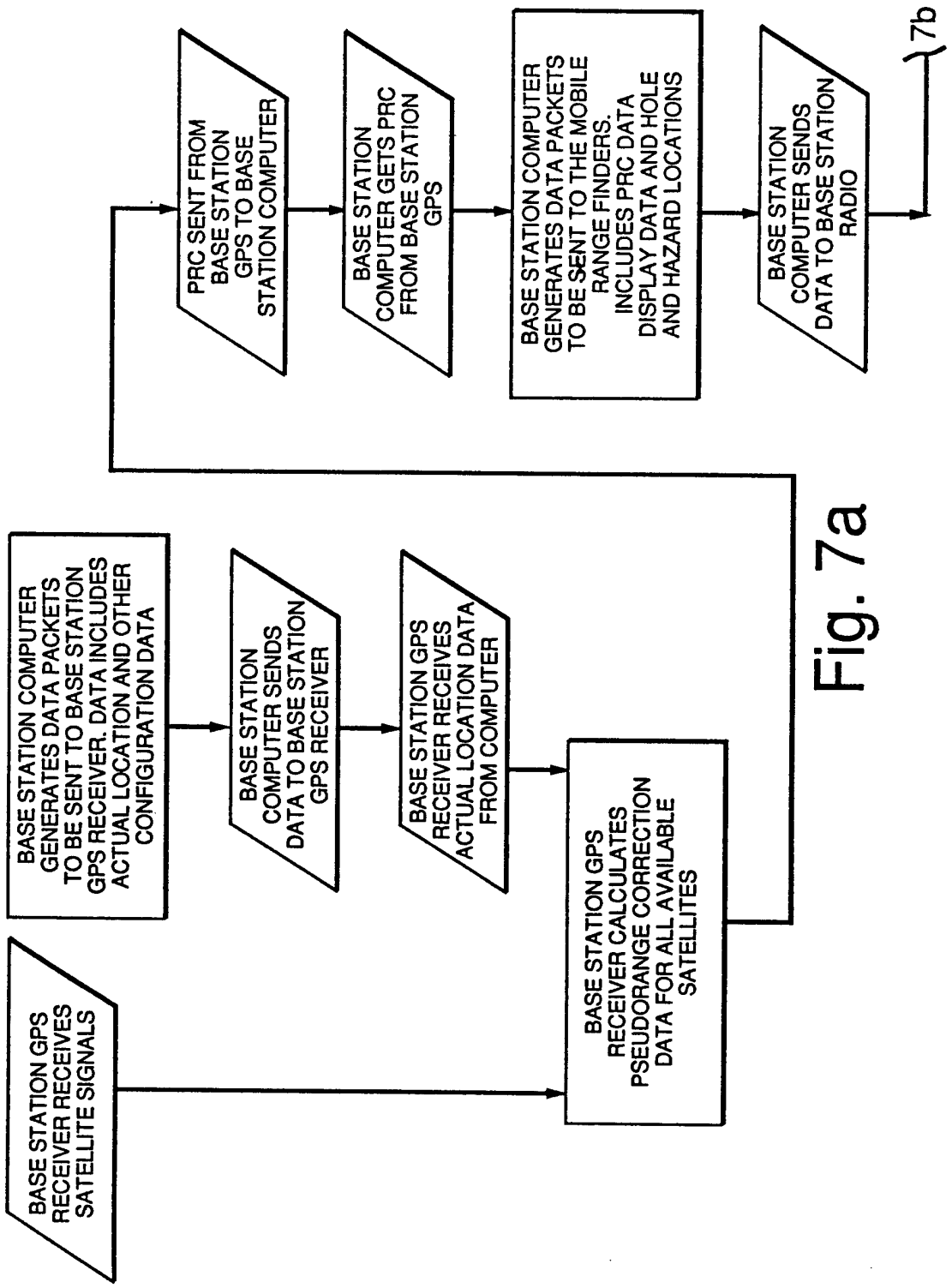
BASE STATION GPS RECEIVER RECEIVES SATELLITE SIGNALS
BASE STATION COMPUTER GENERATES DATA PACKETS TO BE SENT TO BASE STATION GPS RECEIVER. DATA INCLUDES ACTUAL LOCATION AND OTHER CONFIGURATION DATA
BASE STATION COMPUTER SENDS DATA TO BASE STATION GPS RECEIVER
BASE STATION GPS RECEIVER RECEIVES ACTUAL LOCATION DATA FROM COMPUTER
BASE STATION GPS RECEIVER CALCULATES PSEUDORANGE CORRECTION DATA FOR ALL AVAILABLE SATELLITES
PRC SENT FROM BASE STATION GPS TO BASE STATION COMPUTER
BASE STATION COMPUTER GETS PRC FROM BASE STATION GPS
BASE STATION COMPUTER GENERATES DATA PACKETS TO BE SENT TO THE MOBILE RANGE FINDERS. INCLUDES PRC DATA DISPLAY DATA AND HOLE AND HAZARD LOCATIONS
BASE STATION COMPUTER SENDS DATA TO BASE STATION RADIO
7b

Fig. 7a

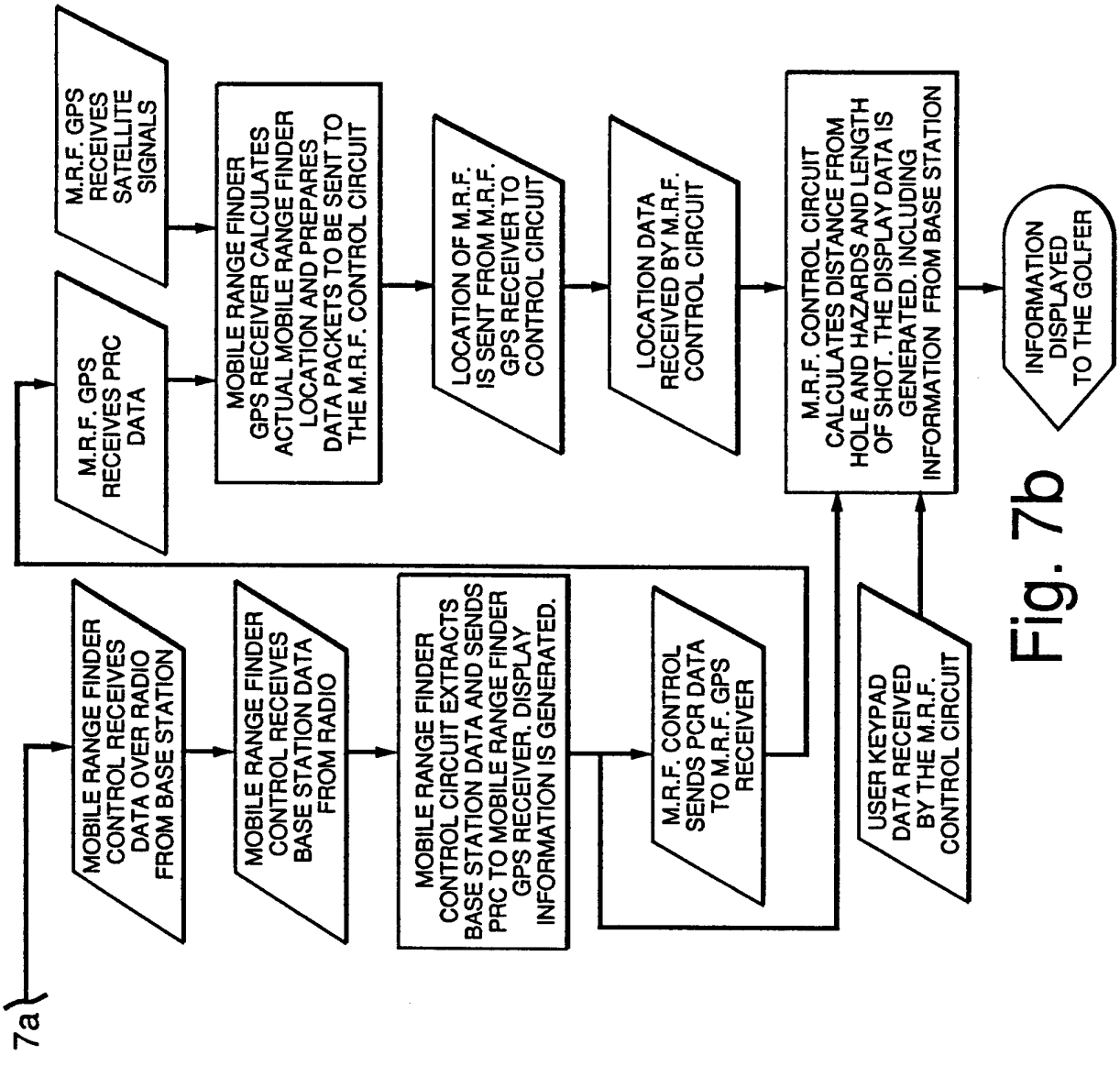
7a
MOBILE RANGE FINDER CONTROL RECEIVES DATA OVER RADIO FROM BASE STATION
MOBILE RANGE FINDER CONTROL RECEIVES BASE STATION DATA FROM RADIO
MOBILE RANGE FINDER CONTROL CIRCUIT EXTRACTS BASE STATION DATA AND SENDS PRC TO MOBILE RANGE FINDER GPS RECEIVER. DISPLAY INFORMATION IS GENERATED.
M.R.F. CONTROL SENDS PCR DATA TO M.R.F. GPS RECEIVER
USER KEYPAD DATA RECEIVED BY THE M.R.F. CONTROL CIRCUIT
M.R.F. GPS RECEIVES PRC DATA
M.R.F. GPS RECEIVES SATELLITE SIGNALS
MOBILE RANGE FINDER GPS RECEIVER CALCULATES ACTUAL MOBILE RANGE FINDER LOCATION AND PREPARES DATA PACKETS TO BE SENT TO THE M.R.F. CONTROL CIRCUIT
LOCATION OF M.R.F. IS SENT FROM M.R.F. GPS RECEIVER TO CONTROL CIRCUIT
LOCATION DATA RECEIVED BY M.R.F. CONTROL CIRCUIT
M.R.F. CONTROL CIRCUIT CALCULATES DISTANCE FROM HOLE AND HAZARDS AND LENGTH OF SHOT. THE DISPLAY DATA IS GENERATED. INCLUDING INFORMATION FROM BASE STATION
INFORMATION DISPLAYED TO THE GOLFER

Fig. 7b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/00848

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G01S 5/14, 5/02; A63B 71/06, 57/00
US CL :364/561, 444, 449; 273/32R, 32H; 340/323R
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 364/561, 444, 449, 562, 410; 273/32R, 32H, 34R, 439; 340/323R, 988,991, 992, 993; 342/357, 457, 118, 123, 126, 352, 450

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS search terms: GPS, golf, differential corrections, pseudorange

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US, A, 5,364,093 (HUSTON ET AL) 15 November 1994, col. 2, lines 5-65; col. 3, lines 35-68; col. 5, lines 1-27; col. 5, line 59 - col. 6, lines 32; col. 4, lines 1-68; col. 6, lines 39-53; col. 6, line 25 - col. 7, line 17.	1-10
Y,P	US, A, 5,359,521 (KYRTSOS ET AL) 25 October 1994, col. 3, line 50 - col. 4, line 68; col. 5, line 39 - col. 13, line 66	1-10
A	US, A, 5,044,634 (DUDLEY) 03 September 1991, col. 1, line 10 - col. 3, line8	1-10
Y	US, A, 5,225,842 (BROWN ET AL) 06 July 1993, col. 4, line 49 - col. 7, line 68	1-10

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 07 MARCH 1995	Date of mailing of the international search report 04MAY1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer EMMANUEL TODD VOELTZ Telephone No. (703) 305-9714

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/00848

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,119,102 (BARNARD) 02 June 1992, col. 4, line 30 - col. 7, line 15	1-10
A	US, A, 4,703,444 (STORMS, JR ET AL) 27 October 1987, col. 2, line 50 - col. 6, line 44	1-10